Cloud Computing-based Delivery of Drought Information at Multiple Scales

A collaboration between Arizona State University (ASU), California State University Monterey Bay (CSUMB) and Planetary Skin Institute (PSI)

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Current-Generation Drought Information in Latin America

National drought monitoring typically consists of rainfall information:

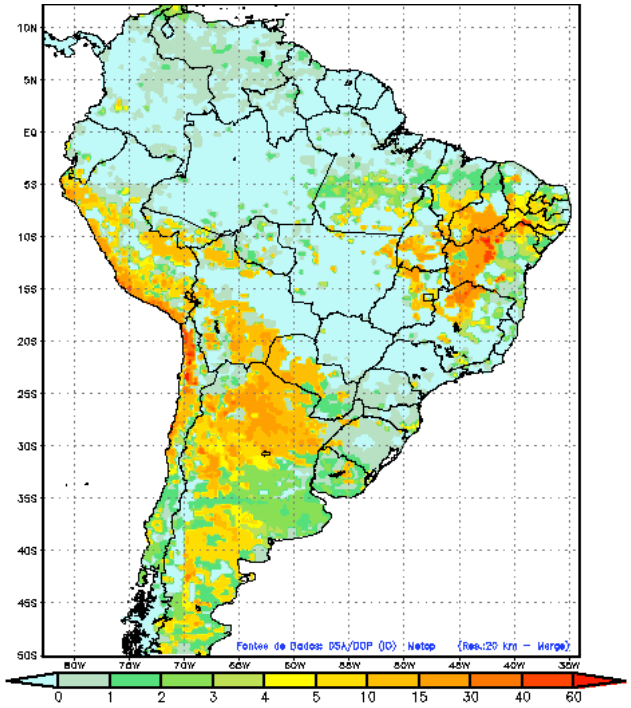
- Brazilian “Monitoramento de Secas” utilizes satellite rainfall products (TRMM) to map days since rainfall. Many other Latin American countries have no drought monitoring.

Monitors based on precipitation products only measure meteorological drought:

- More severe agricultural or hydrological drought require monitoring vegetation, soil and river conditions as rainfall information does not necessarily depict all stages.
- Satellite remote sensing and hydrological modeling can provide additional products to help monitor drought conditions.

Designing a drought monitor also requires interacting with stakeholders to understand their applications and needs and receive iterative feedback.

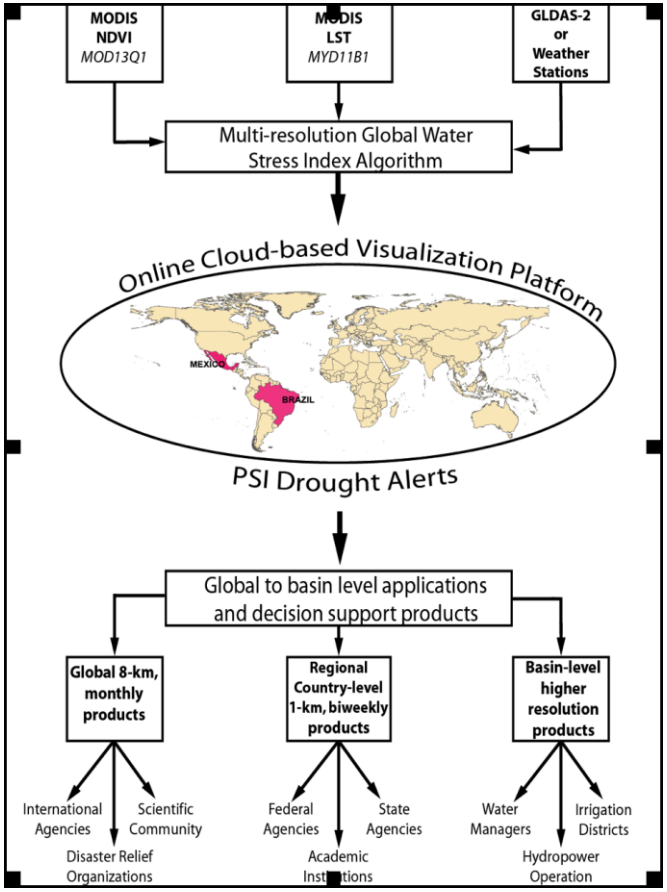
Example of the May 14, 2012 Brazil Monitor



Water Resources Drought Monitor

Cloud-based Visualization Tool for Drought at Multiple Scales is based on:

- An advanced online tool for scientific data discovery and decision maker interaction:
  - Populated with up-to-date and relevant drought indices and ancillary data sets from remote sensing and geographical data layers.
  - Presented in contextual manner that enhances the user experience in data discovery at multiple scales ranging from basin to global.
- A combination of remote sensing and model-based drought products that utilize more direct information on the land surface:
  - Water stress index is based on MODIS NDVI and LST fields to provide drought information.
  - Watershed models to simulate soil moisture and infer drought conditions.
- An interdisciplinary team composed of domain experts and stakeholders including users and decision makers in Brazil and Mexico.



Online visualization platform for drought monitoring using a multi-resolution, global water stress index from remote sensing

Water Resources Drought Monitor

Products to be integrated into Drought Monitor:

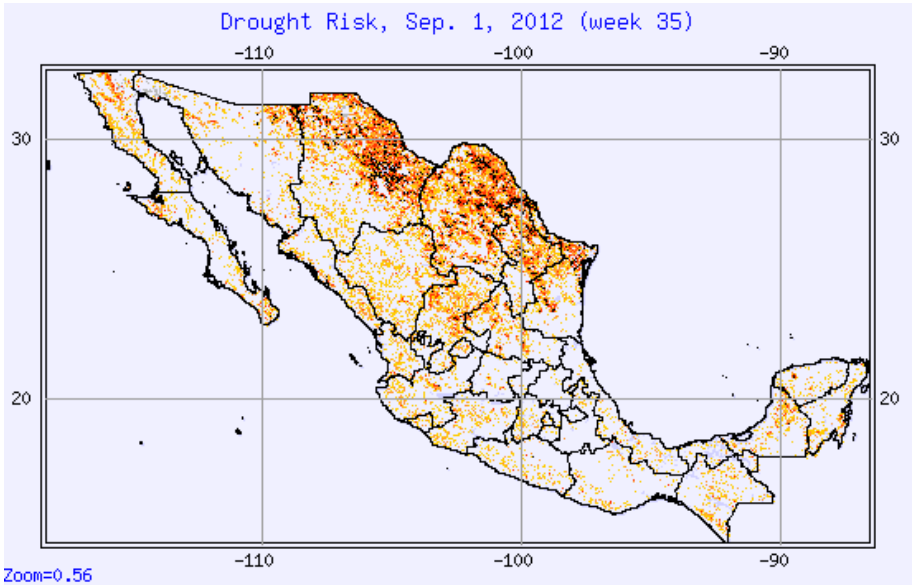
Earth Science Product	Application	Source	Link
MODIS NDVI	Vegetation spectral reflectance	MOD13Q1/MYD13Q1; Global 16-d, 250-m	http://glovis.usgs.gov/ https://lpdaac.usgs.gov/lpdaac/get_data/data_pool
MODIS LST	Surface thermal temperature	MOD11A2/MYD11A2; Global 8-d, 1-km	http://glovis.usgs.gov/ https://lpdaac.usgs.gov/lpdaac/get_data/data_pool
MODIS Land Cover	Annual land cover classification	MCD12Q1; Global, yearly, 500-m	http://glovis.usgs.gov/ https://lpdaac.usgs.gov/lpdaac/get_data/data_pool
STAR Global VH	Vegetation health and condition indices	AVHRR vegetation health , 16-km, 7-d	http://www.star.nesdis.noaa.gov/smcd/emb/vci/VH/vh_ftp.php
MERRA	Gridded precipitaton and temperature reanalysis product	NASA Goddard GMAO Office	http://goldsmr2.sci.gsfc.nasa.gov/data/s4pa/MERRA_MONTHLY/MATMNXLND.5.2.0
GWSP	Global water supply and demand estimate	UNH hydrologic model outputs	http://atlas.gwsp.org
PSI ALERTS	Agricultural and land conversion	PSI R&D products in Brazil and Mexico	http://ourplanetaryskin.org/ps/is/cs/run.php
GTOPO30/HYDRO1K	Terrain data & derivatives	USGS 30 arc-second digital elevation model	http://eros.usgs.gov/#/Find_Data/Products_and_Data_Available/gtopo30/hydro
GIAM V2.0	Irrigated and rainfed areas	Analyses of AVHRR, SPOT datasets	http://www.iwmigiam.org/info/main/index.asp
GRanD	Reservoir and dam database	Multiple international and country agencies	http://atlas.gwsp.org/index.php?option=com_content&task=view&id=207&Itemid=68
WWF Ecoregions	Global terrestrial ecoregions	Satellite-based global classification	http://www.worldwildlife.org/science/ecoregions

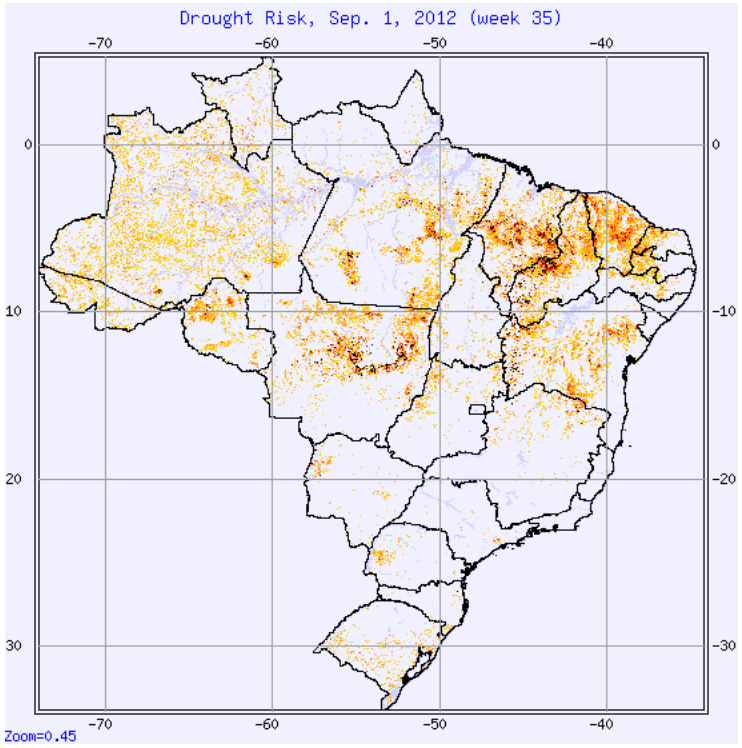
Drought Monitor Stakeholders

A focus of the effort will be in Brazil and Mexico:

1) Large, developing countries with growing populations.
2) Consisting of arid and semiarid regions with high amounts of irrigated agriculture prone to drought.
3) Currently under intensive/extensive drought.

Current Drought in Mexico and Brazil from Vegetation Health





Drought Monitor Stakeholders

Stakeholders and decision-makers from Brazil and Mexico include:

- The national space research agency in Brazil (INPE, http://www.inpe.br/) in the Ministry of Science and Technology.
- An agency for natural disaster monitoring in Brazil (CEMADEN, http://www.cemaden.gov.br)
- The national water commission in Mexico (CONAGUA, http://www.cna.gob.mx/)
- The state water commission in Sonora, Mexico (CEA, http://www.ceasonora.gob.mx/)
- A large irrigation district in Sonora, Mexico (DRRY, http://www.drryaqui.com.mx/)

Current stakeholder capabilities vary from more sophisticated (INPE) to more limited (DRRY)

Brazil:

INPE

Cemaden
Centro Nacional de Monitoramento e Alertas de Desastres Naturais

Mexico:

CONAGUA
Comisión Nacional del Agua

DISTRITO DE RIEGO DEL RIO YAQUI

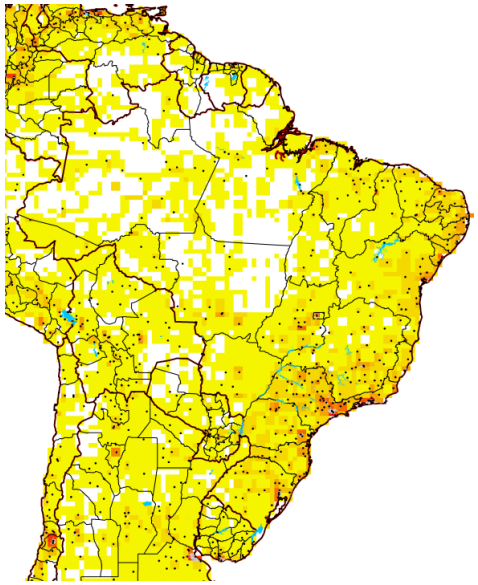
CEA
COMISIÓN ESTATAL DEL AGUA

Drought Monitor Elements: Ancillary Information

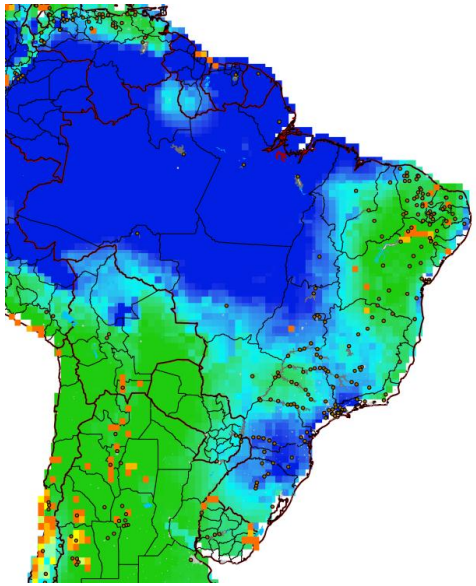
We have collected and processed a large number of global GIS data sets:

1) Political, infrastructure, terrain, land cover and hydrographic databases.
2) Annual and monthly climate indices and high-resolution reanalysis products.
3) Water demands, population distribution and irrigation estimates.

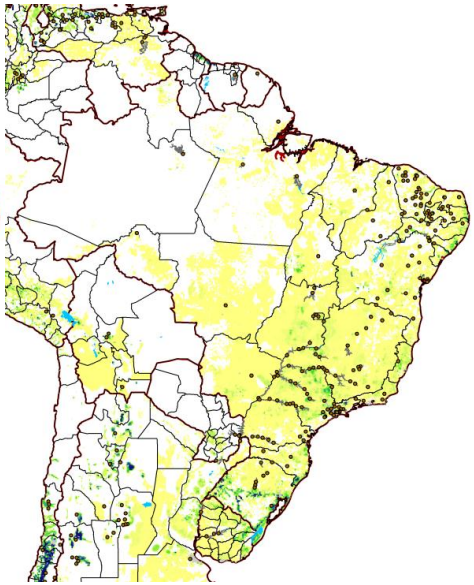
Example GIS overlays for Brazil and other parts of South America



Administrative Units and Total Population (2000)



Annual Runoff (1950-2000) and Irrigation Withdrawals (1961-1990)



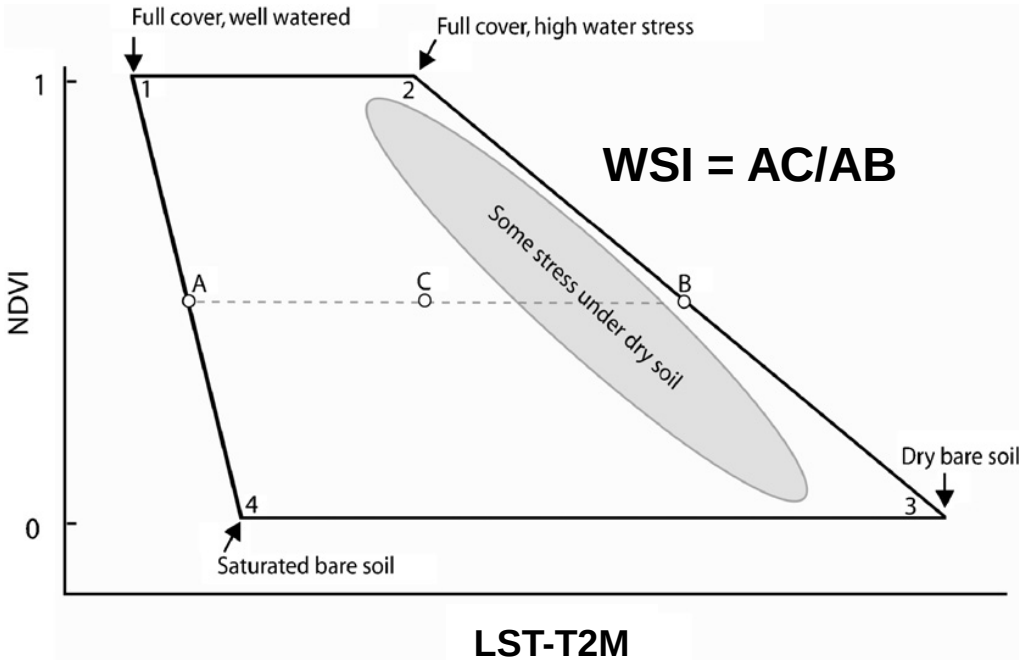
Irrigation Area Percentages (2007)

HYDRO1K Basin Boundaries and River Networks

Drought Monitor Elements: Remote Sensing

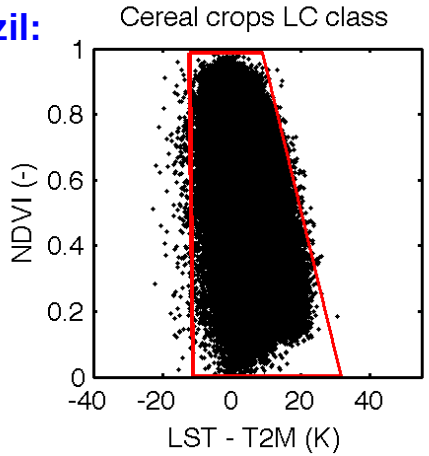
Water Stress Index (WSI) is an adaptation of the trapezoidal method (Moran et al. 1994):

1) Relies on a conceptual mapping of vegetation water stress onto the NDVI and LST-T2M space.
2) Requires a land-cover specific calibration of the trapezoidal vertices, achieved for MODIS classes.

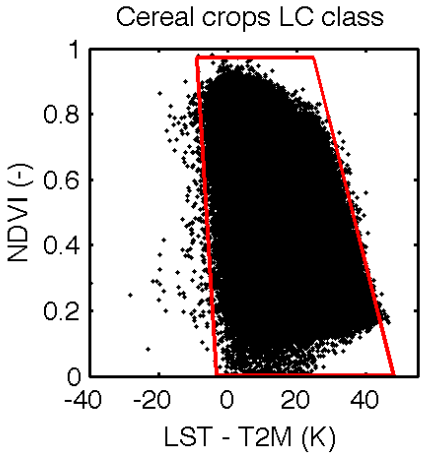


WSI = AC/AB

Brazil:



Mexico:

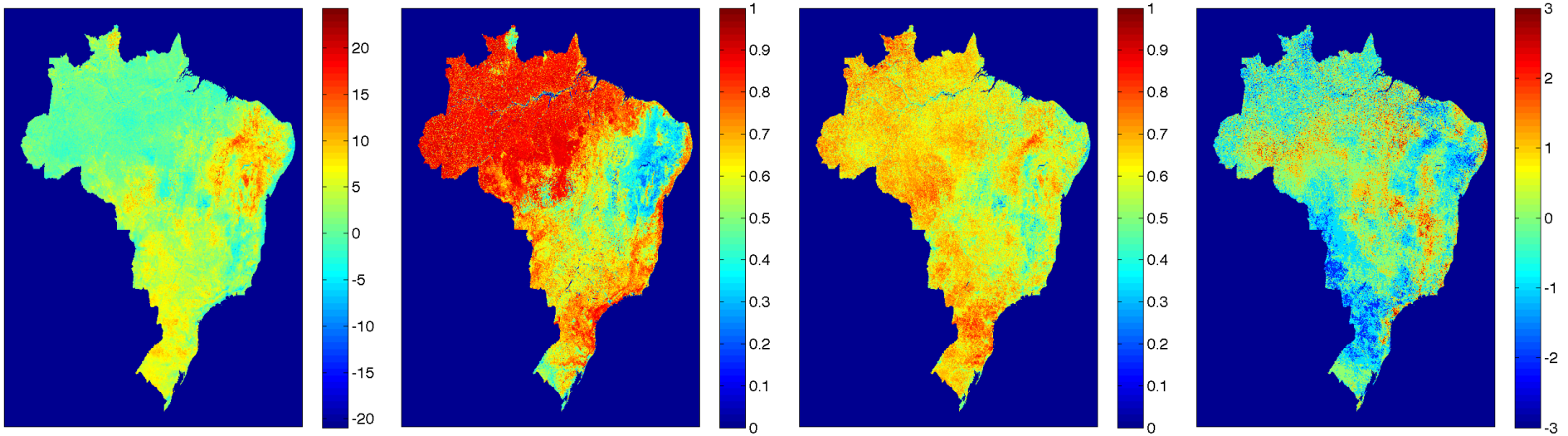


Drought Monitor Elements: Remote Sensing

We downloaded, preprocessed and projected the following products (2002-2012) to derive the water stress index (WSI):

1) Land Surface Temperature (LST): MODIS MYD11A2.005 at 1 km, 8 days.
2) Normalized Difference Vegetation Index (NDVI): MODIS: MYD13A2.005 at 1 km, 16 d.
3) Air temperature (T2M): MERRA: tavg1_2d_slv_Nx at 0.5° lat x 0.67° lon, 1 h.
4) Land cover classes: MODIS MCD12Q1 at 500 m for year 2010.

Examples of remote sensing products for Brazil for June 17, 2012

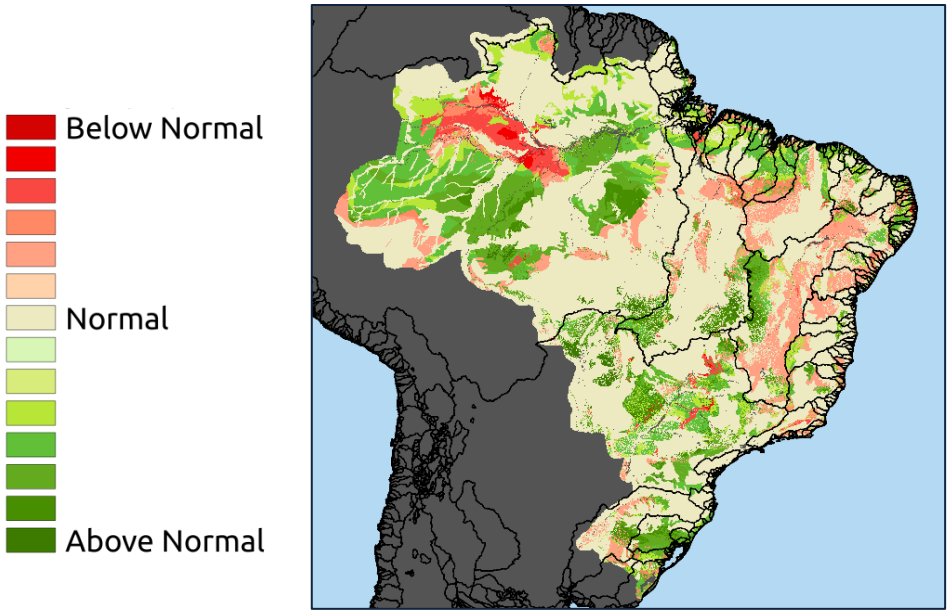


LST-T2M **NDVI** **WSI** **WSI Anomaly**

Drought Monitor Elements: Hydrologic Modeling

We applied the CASA Express, a sub-version of the NASA-CASA ecosystem production and trace gas model, to produce soil moisture estimates:

1) Necessary inputs include: land cover, soil texture, soil depth (estimated from remote sensing of land cover), temperature, and precipitation at monthly intervals (MERRA).
2) Volumetric Water Content (VWC) from the third and deepest soil layer was produced at monthly intervals and resolutions dictated by the MODIS land cover data.
3) Anomalies in VWC were computed in the same fashion as for WSI.



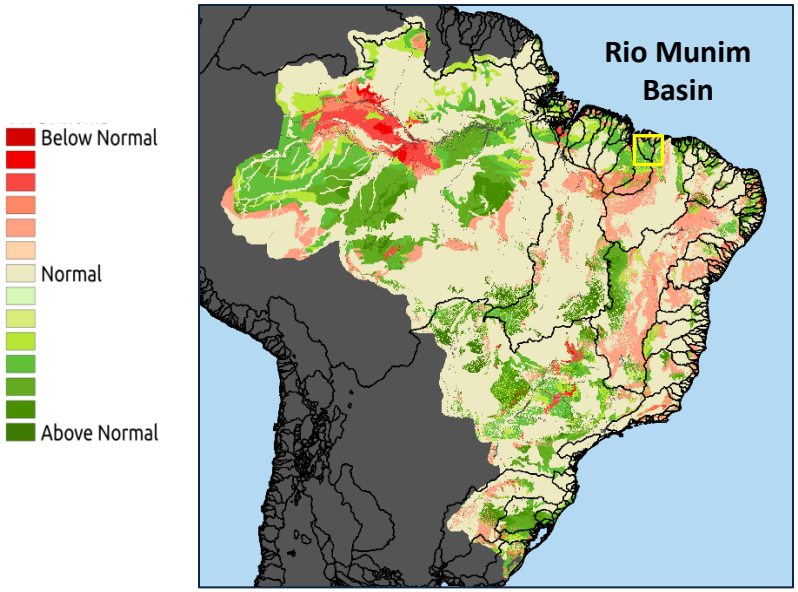
Anomaly calculations for VWC and WSI pixels over period 2000-2012 obtained as:

$$Anomaly = \frac{X - \overline{X}}{\sigma}$$

based on the long-term mean and standard deviation at that site.

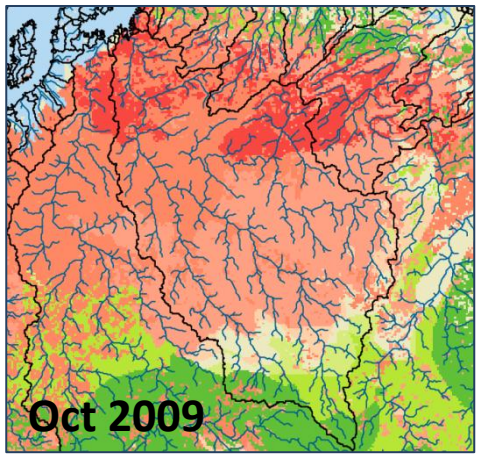
A qualitative classification was generated for stakeholder interpretation.

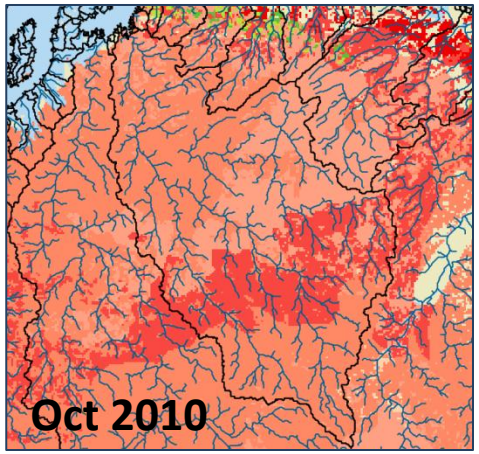
Drought Monitor Elements: Hydrologic Modeling

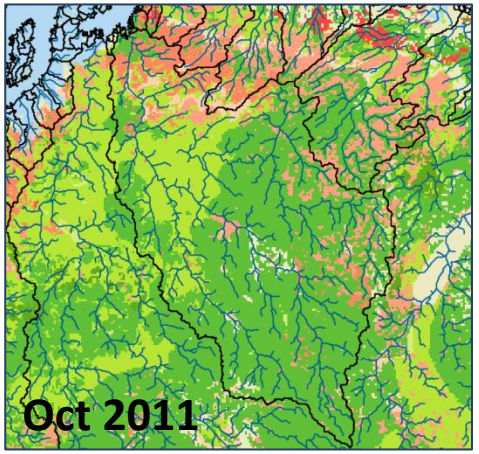


Stakeholder relevant visualizations are possible at fine resolutions where:

1) VWC or WSI anomalies provide details at 1-km and 16-day or 1 month intervals .
2) Spatial variations are detected within an irrigation district or a management area.
3) Time series of drought products can be overlaid with other ancillary information.







Drought Monitor Elements: Visualization Platform

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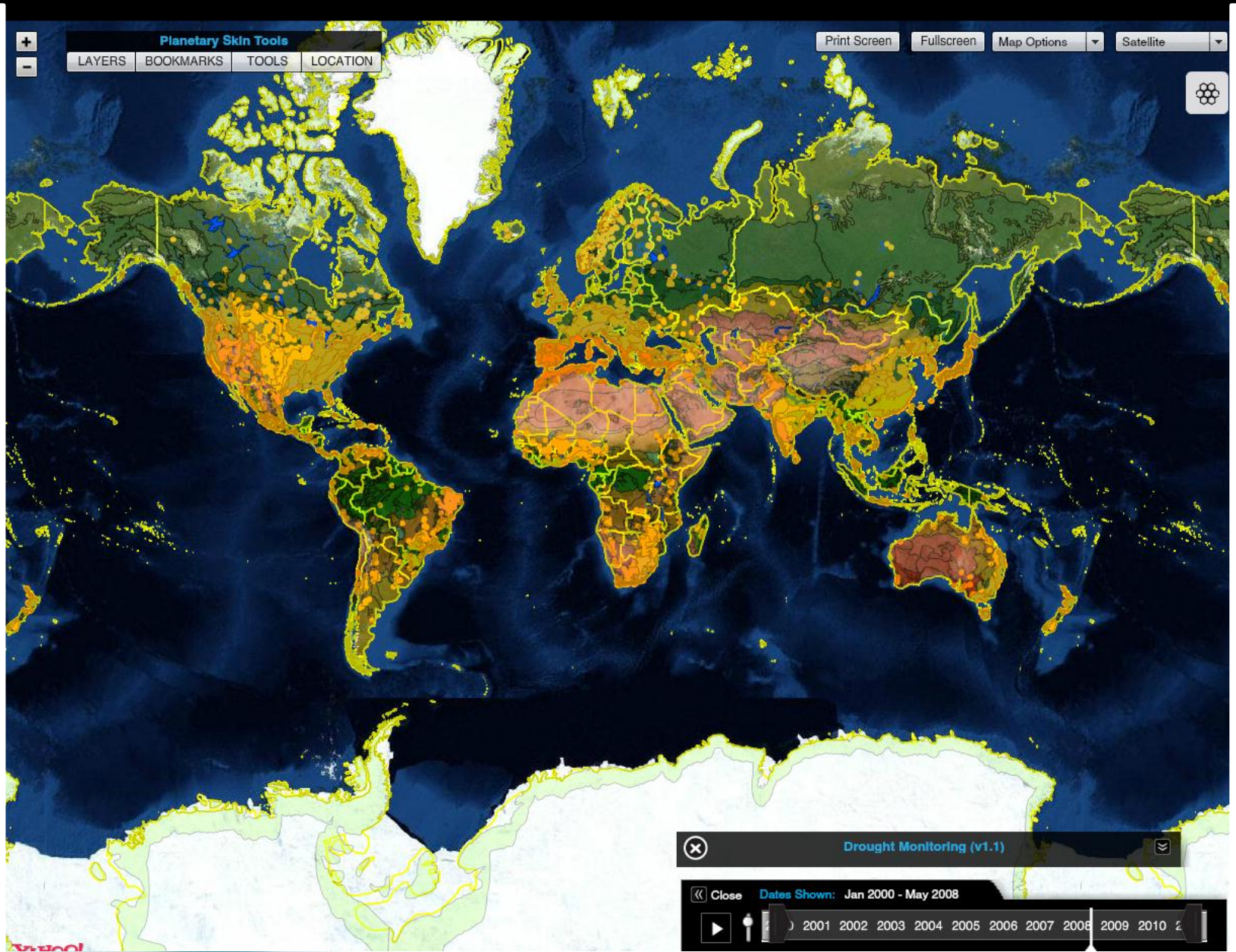

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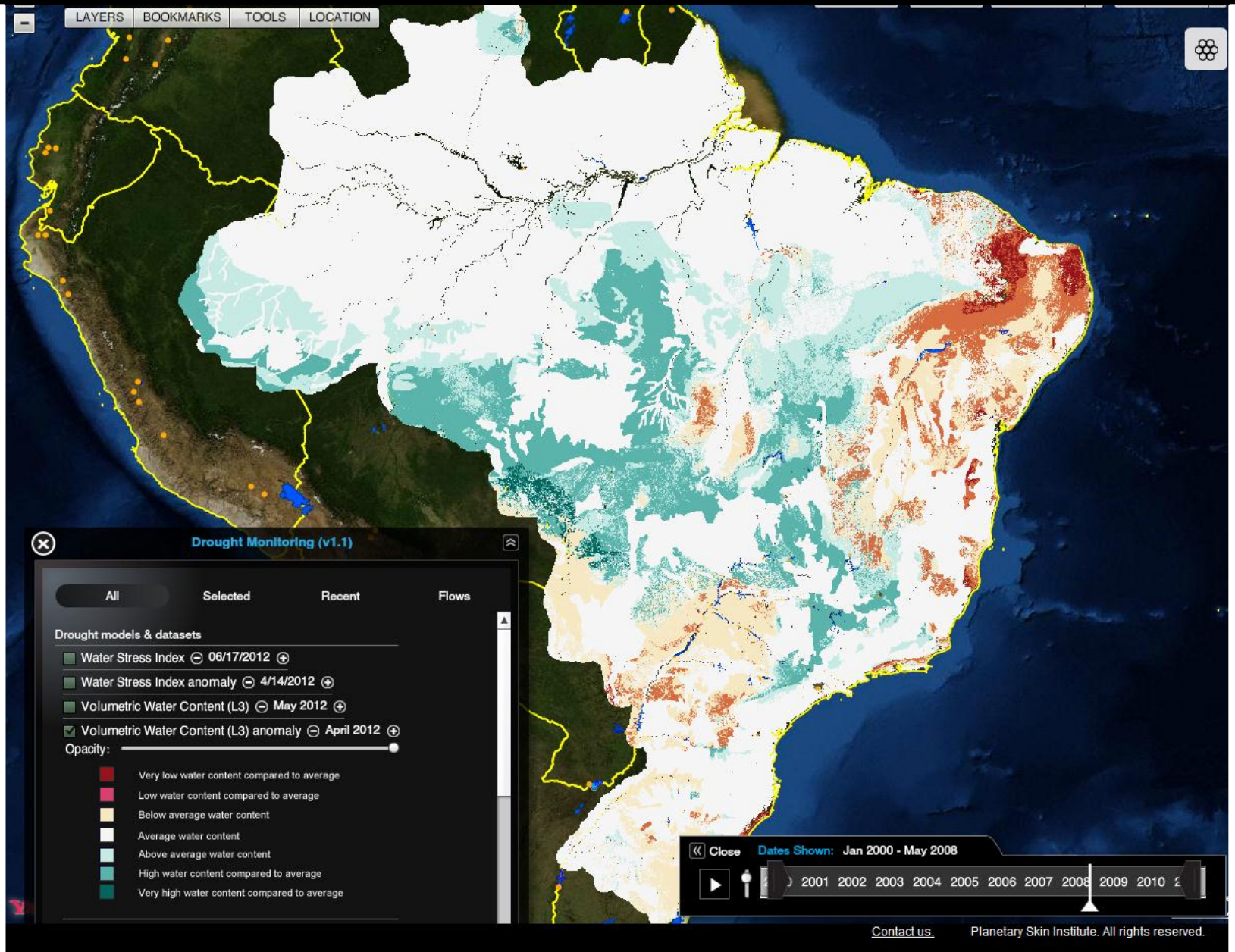

Assessing Drought Monitor Impacts

The impacts of the drought monitoring platform will be assessed through our interactions with stakeholder groups in Brazil and Mexico:

- For advanced research agencies:
  - How do the products and decision flows generated from them improve their current abilities to have access to timely, high-resolution drought information?
  - How can the drought monitor respond more effectively to their audience (translation, terminology or visualization preferences)?
- For operational agencies with more limited capacity (in addition to above):
  - How can the platform be tailored for the specific cases of most interest to the agency?
  - What additional training is required for adoption of the platform in the operational setting?

Interactions will take place through web-mediated conference calls (WebEx) with technical staff at the agency level. Potential for visits to demonstrate the capabilities of the platform and to obtain in-person feedback.

Next steps:

- Refinement of the visualization to group products together in decision flows.
- Identifying data analysis and time series tools to build on top of the products.
- Hydrologic model applications at basin-scales within Brazil and Mexico.